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Original Research

Evaluation of scintigraphic findings and non-contrast enhanced thorax CT findings in patients with pulmonary embolism

Scintigraphic and CT findings in pulmonary thromboembolism

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Abstract

Aim: Pulmonary embolism (PE) is a disease with a high mortality rate that occurs as a result of the migration of thrombus in the deep veins of the lower extremities into the pulmonary circulation. Contrast-enhanced CT and V/P scintigraphy are two commonly used methods for imaging. This study aims to determine the frequency of parenchymal and non-parenchymal findings on non-contrast CT in patients who are clinically suspected to have PE but who cannot undergo contrast-enhanced CT-angiography and who are diagnosed with PE by lung perfusion scintigraphy.

Material and Methods: Thirty-nine patients who were admitted to Tokat State Hospital between 2015 and 2022 with a preliminary diagnosis of pulmonary embolism and who underwent lung perfusion scintigraphy and non-contrast CT scans in the same week were evaluated retrospectively.

Results: When computed tomography findings were evaluated in patients with pulmonary embolism, wedge-shaped opacity was present in 3 patients (20%) but not present in 12 patients (80%); consolidation was present in 6 patients (40%) and absent in 9 patients (60%); dilatation in the main pulmonary artery was present in 7 patients (46.7%) and absent in 8 patients (53.3%).Ground-glass opacity was present in 11 patients (73.3%), absent in 4 patients (26.7%); pleural effusion was present in 4 patients (26.7%) but not in 11 patients (73.3%); atelectasis was present in 4 patients (26.7%) but not in 11 patients (73.3%).

Discussion: In our study, there was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the detection of wedge-shaped opacity, consolidation, dilatation in the main pulmonary artery, ground glass attenuation, pleural effusion and atelectasis in thorax CT.

Keywords

Pulmonary Embolism, Perfusion Scintigraphy, Computerised Tomography, Macroaggregated Albumin

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Introduction

Pulmonary embolism (PE) is a disease with a high mortality rate that occurs as a result of the migration of thrombus in the deep veins of the lower extremities into the pulmonary circulation, which prevents blood flow in the pulmonary arteries. Approximately 95% of pulmonary embolism originates from deep vein thrombosis of the lower extremities [1]. The annual incidence of PE is 3-6 per 10,000 people, and it ranks third among cardiovascular-related deaths [2]. Early diagnosis and treatment significantly reduce mortality in patients with pulmonary embolism [3]. However, symptoms and clinical findings are not specific to PE, and many thoracic pathologies such as pneumonia, pleural-pericardial effusion, and aortic dissection are among the differential diagnosis [4]. Gayen et al. reported that lung perfusion returned to normal following mechanical thrombectomy, patients immediately experienced an improvement in perfusion score; scores continued to improve at follow-up. in PE patients [5]. Due to this rapidly changing course of PE, diagnosis and imaging examinations should be performed as soon as possible. Patients with clinically suspected low/moderate pulmonary embolism but with a positive D-dimer test require imaging. Likewise, imaging methods should be used in patients with a high/likely clinical probability of pulmonary embolism. Contrast-enhanced CT and V/P scintigraphy are two commonly used methods for imaging. Pulmonary arteries are visualized after injection of intravenous contrast material during CT angiography examination. During this examination, pulmonary embolism is observed as filling defects in the pulmonary arteries. CT angiography examination can be performed within a few minutes. In addition to showing the location and burden of the thrombus, CT can also show alternative pulmonary pathologies that can be followed in addition to pulmonary embolism, which will explain the clinical status of the patient. While central and lobar thrombi are detected at a rate of almost 97% with spiral CT examination, segmental thrombi are detected in 68% and subsegmental thrombi in 25% [6,7]. Due to the iodine content of the contrast material, it can cause serious pseudoallergic reactions in people with iodine allergy. One of the most serious side effects of this examination is contrast-induced acute kidney injury, which is defined as an increase in serum creatinine within 48–72 h after intravenous administration of low- or iso-osmolar iodinated contrast media. There is a risk of renal failure and dialysis after this side effect [8]. In addition, there is a risk of developing hyperthyroidism and, rarely, hypothyroidism after the use of intravenous contrast material [9]. CT findings in PE are divided into vascular changes and parenchymal changes. The primary vascular finding is an intraluminal filling defect in the pulmonary arteries. The use of pulmonary angiography is limited due to its limited sensitivity-specificity, wide interobserver variability, and recent developments in CT angiography [10]. However, the necessity of contrast material for both examinations limits its use in cases where the use of contrast is contraindicated.

As perfusion is interrupted and ventilation continues in the lung tissue fed by the occluded vascular bed, an alveolar dead space area arises and hyperventilation develops. Alveolar hypocapnia occurs as a result of dead space ventilation. Bronchoconstriction and a tendency to alveolar collapse develop distal to the obstruction. Surfactant production is impaired in the alveolar area distal to the obstruction; this leads to alveolar collapse and alveolar edema. Parenchymal regions are formed where the ventilation-perfusion balance is disturbed. In the case of PE, when the non-perfused lung segment is ventilated, the lung dead space increases, resulting in hypoxia-induced dyspnea. In addition, arterial embolism in the lung may disrupt the local balance, causing hemorrhages, atelectasis, pleural effusion, and pleuritic pain [11]. Although they do not affect hemodynamics, small distal emboli create areas of alveolar hemorrhage, usually causing mild hemoptysis, pleural effusion and pleuritis. This clinical condition is known as “pulmonary infarction” [12].

In young patients with normal chest X-rays, pregnant women, those with a history of severe contrast allergy, those with renal failure, low-risk patients with multiple myeloma and paraproteinemia, in health institutions without pulmonary CT angiography, where the clinical probability is high but pulmonary CT angiography cannot detect embolism (non-diagnostic condition) lung perfusion scintigraphy can be used [13]. Ventilation/perfusion SPECT is a method with a specificity of 96-98% and a sensitivity of 96-99% in the diagnosis of PE [14]. In the lung V/P SPECT examination, preserved ventilation with decreased perfusion is evaluated in favor of PE (mismatch defect). In the subacute period, when the thrombus is partially resolved, false-negative results can be obtained. In addition, radiation pneumonia, congenital vascular anomalies, and venous occlusive diseases may cause a similar appearance in addition to PE [15].

This study aims to determine the frequency of parenchymal and non-parenchymal findings on non-contrast CT in patients who are clinically suspected to have PE but who cannot undergo contrast-enhanced CT-angiography and who are diagnosed with PE by lung perfusion scintigraphy.

Material and Methods

Patient Population

Thirty-nine patients who were admitted to Tokat State Hospital between 2015 and 2022 with a preliminary diagnosis of pulmonary embolism and who underwent lung perfusion scintigraphy and non-contrast CT scans in the same week were evaluated retrospectively. Those who had more than a week between lung perfusion scintigraphy images and CT images were not included in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Medical records, scintigraphy findings, and other data of the patients were evaluated retrospectively. The study was carried out with the permission of Tokat Gaziosmanpasa University Medical Faculty Clinical Researches Ethics Committee (Date:10.04.2023, Decision No:83116987-246).

Lung Perfusion ***Scintigraphy Protocol***

Lung perfusion scintigraphy was performed using on average 4 mCi 99mTc-labelled human albumin (MAA) with a diameter of 15–100 μm. The patient lays in the supine position during the injection to allow maximum blood flow to lung apices. The radiopharmaceutical particles then embolize in the capillaries and provide a map of pulmonary blood flow. After the radiopharmaceutical injection, planar and SPECT images were obtained. Lung perfusion scintigraphy imaging was performed using the MEDISO AnyScan S gamma camera system with a general-purpose collimator, 64×64 matrix and 64 rotational steps of a dual head gamma camera (Mediso Medical Imaging Systems Ltd., Budapest, Hungary).

The COVID-19 pandemic has caused very important effects in our country as well as all over the world. One of these can be stated as reducing the chance of performing ventilation scintigraphy in patients with suspected pulmonary embolism. According to the "Guide For Nuclear Medicine Applications During The COVID-19 Outbreak" published in our country during this period the following suggestions have been made: "Lung ventilation scintigraphy must not be performed if there are findings mimicking COVID-19 pneumonia such as non-segmental perfusion defects, non-wedge shaped perfusion defects, resembling lung parenchymal disease" and "Due to the presence of aerosol formation with the devices used for ventilation scintigraphy in this period, lung ventilation study should not be performed in patients with probable PE during the pandemic" [16]. Instead, it has been stated that it would be more appropriate to use only perfusion scintigraphy, whose sensitivity (82%) and specificity (96%) of perfusion-only study are inferior to combined ventilation/ perfusion study, these values are still high in the diagnosis of pulmonary embolism. Perfusion-only Modified PIOPED II criteria, using only perfusion scintigraphy, were frequently used in this period. According to these criteria, patients are divided into three groups: PE present, nondiagnostic, and PE absent. According to these criteria, the presence of ≥2 large mismatched (perfusion scintigraphy: Chest X-ray) (Q:CXR) segmental defects is reported to have pulmonary embolism. According to these criteria, in the presence of nonsegmental perfusion defect < CXR lesion, 1–3 small segmental defects, solitary matched (Q:CXR) defect (≤1 segment) in mid or upper lung, stripe sign and solitary large pleural effusion is reported that there is no pulmonary embolism. In the presence of all other findings, it is reported as nondiagnostic [17]. In our study, perfusion-only modified PIOPED II criteria were used in the diagnosis of pulmonary embolism.

CT Protocol

Thorax CT images were performed in the supine position, covering the lower cervical vertebrae and the upper lumbar vertebrae, with a 128-slice GE Revolution CT scanner (GE Healthcare, Milwaukee, WI). Acquisitions were performed during a single breath hold. No contrast material was used during the procedure. Imaging parameters for non-contrast thorax CT were set as 120 kV, 400 mA, 400 ms rotation time, and 1 mm section thickness. CT images were retrospectively reviewed and interpreted by an expert radiologist using cine mode at a PACS workstation. Images were viewed at standard lung (window width, 1600 UH, window level, −400 UH) and mediastinal settings (window width, 350 UH, window level, 50 UH). The readers were blinded to clinical data. All peripheral parenchymal and pleural findings were evaluated for each single patient.

Study design

A diagnosis of PE was confirmed based on lung perfusion scintigraphy visualization of PE with perfusion-only Modified PIOPED II criteria. Images were analyzed for the presence of perfusion defects within the lung. In addition, lung and mediastinum window images were retrospectively assessed for the following abnormalities: the presence of pleura-based wedge-shaped opacity, pleural effusion, isolated atelectasis, consolidation, dilatation of the main pulmonary artery, and ground glass attenuation. Wedge-shaped opacity, consolidation, ground-glass opacity, pleural effusion and atelectasis areas mentioned in patients with pulmonary embolism according to perfusion scintigraphy are mismatches. Atelectasis was defined as a region of increased attenuation larger than 3 mm. The diagnosis of pulmonary embolism was made by evaluating lung perfusion scintigraphy findings, thorax CT findings, clinical findings, lower extremity venous Doppler USG and laboratory tests such as D-dimer. Patients who did not have thorax CT imaging within the same week as lung perfusion scintigraphy were not included in our study.

Statistical Analysis

Analysis was performed using the SPSS Statistical Software program (SPSS version 23.0, SPSS Inc., Chicago). A p-value of <0.05 was considered statistically significant during the tests. During the comparison of categorical and numerical data, the Independent Student's t-test was used for the normally distributed data, and the Mann-Whitney U test was used for the analysis of non-normally distributed data. All continuous variables of the study were described by descriptive statistics such as mean, median, and standard deviation (SD). Categorical variables were described by frequency and percentages. Differences between patients with and without PE were evaluated on CT images for the presence of pleura-based, wedge-shaped opacity, pleural effusion, isolated atelectasis, consolidation, dilatation of the main pulmonary artery, ground glass attenuation using the Chi-Square test.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

Of the 39 patients included in the study, 23 (59%) were females and 16 (41%) were males. The average age of the patients was 67.8 (range=32-90) years. While lung perfusion scintigraphy was normal in 24 (61.5%) patients, lung perfusion scintigraphy was reported to be compatible with pulmonary embolism in 15 (38.5%) patients. When computed tomography findings were evaluated in patients with pulmonary embolism, wedge-shaped opacity was present in 3 patients (20%) but not present in 12 patients (80%); consolidation was present in 6 patients (40%) and absent in 9 patients (60%); dilation in the main pulmonary artery was present in 7 patients (46.7%) and absent in 8 patients (53.3%). Ground-glass opacity was present in 11 patients (73.3%), absent in 4 patients (26.7%); pleural effusion was present in 4 patients (26.7%) but not in 11 patients (73.3%); atelectasis was present in 4 patients (26.7%) but not in 11 patients (73.3%). When computed tomography findings were evaluated in patients with no findings compatible with pulmonary embolism, wedge-shaped opacity was present in 1 patient (4.2%) but not present in 23 patients (95.8%); consolidation was present in 5 patients (20.8%) and absent in 19 patients (79.2%); dilation in the main pulmonary artery was present in 8 patients (33.3%) and absent in 16 patients (66.7%). Ground-glass opacity was present in 17 patients (70.8%), absent in 7 patients (29.2%); pleural effusion was present in 10 patients (41.7%) but not in 14 patients (58.3%); atelectasis was present in 7 patients (29.2%) but not in 17 patients (70.8%). There was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the detection of wedge-shaped opacity in thorax CT ($p>0.05$). There was no statistically significant difference between the presence of pulmonary embolism on lung perfusion scintigraphy and consolidation on thorax CT ($p>0.05$). There was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the dilatation in the main pulmonary artery in thorax CT ($p>0.05$). There was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the ground glass attenuation in thorax CT ($p>0.05$). There was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the pleural effusion in thorax CT ($p>0.05$). There was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the detection of atelectasis in thorax CT ($p>0.05$) (Table 1).

Table 1. Comparison of lung perfusion scintigraphy and computed tomography findings

	Pulmonary Embolism in Lung Perfusion Scintigraphy				p
	Present		Absent		
Computed Tomography Findings	(+)	(-)	(+)	(-)	
Wedge-Shaped Opacity	3	12	1	23	0.149
Consolidation	6	9	5	19	0.176
Dilatation in the Main Pulmonary Artery	7	8	8	16	0,309
Ground Glass Attenuation	11	4	17	7	0.582
Pleural Effusion	4	11	10	14	0.274
Atelectasis	4	11	7	17	0.582

Discussion

This study aimed to evaluate the parenchymal/non-parenchymal changes that can be observed in computed tomography examination in patients diagnosed with pulmonary embolism by lung perfusion scintigraphy examination and the relationship of these findings with the findings in lung perfusion scintigraphy. Parenchymal changes can be observed in patients with acute pulmonary embolism due to decreased pulmonary perfusion, edema, infarction and bronchoconstriction. In our study, no statistically significant difference was detected in patients with and without pulmonary embolism in terms of thorax computed tomography findings.

In the study conducted by Shah et al. investigating the contrast-enhanced computed tomography findings in patients with acute pulmonary embolism, it was found that 86% of the patients had lung parenchymal changes, and the most common of these was atelectasis [18]. Among these findings, a statistically significant difference between patients with or without pulmonary embolism was found to be peripheral wedge-shaped opacity, which was seen in seven (25%) patients with PE and three (5%) patients without PE (odds ratio, 6.78; 95% CI 5 1.60, 28.62).

A study conducted by Karabulut et al., compared the frequency of pleural and parenchymal abnormalities detected on computed tomography (CT) in patients with and without PE, and examined whether parenchymal findings correlated with the severity of PE [19]. Similarly, in this study, it was determined that the most common finding was atelectasis, and wedge-shaped opacity, pleural effusion and consolidation findings could also be detected. Among these findings, it was determined that the finding that correlated with the severity of pulmonary embolism was wedge-shaped opacity.

In the study conducted by Hochhegger et al. investigating MR findings in patients with acute pulmonary embolism, they investigated that wedge-shaped pleura-based opacities from prior pulmonary infarctions are commonly seen in PE, and these can progress to parenchymal scars, bands, peripheral nodules, cavities or peripheral irregular linear opacities [20].

In the study conducted by Chintapalli et al., which retrospectively investigated 8 patients with pulmonary embolism, it was determined that the most common finding in pulmonary embolism areas in patients with pulmonary embolism was triangular-shaped opacity [21]. In this study, it was stated that although CT is not a primary diagnostic tool in the evaluation of pulmonary embolism, CT may be helpful in the diagnosis of pulmonary embolism, when evaluating an undiagnosed parenchymal density.

However, many studies have compared lung parenchymal findings of patients diagnosed with pulmonary embolism on contrast-enhanced computed tomography. In our study, lung findings obtained in patients diagnosed with lung perfusion scintigraphy were investigated. SPECT/CT is an imaging method that is widely used today and can have significant additional contributions compared to SPECT imaging when used in lung perfusion scintigraphy.

We believe that our study, in which we investigated the parenchymal findings that can be seen in acute pulmonary embolism on lung perfusion scintigraphy and SPECT/CT imaging, will contribute to the literature as it will be one of the rare studies comparing scintigraphic findings with parenchymal findings.

Conclusion

In our study, there was no statistically significant difference between the presence of pulmonary embolism in lung perfusion scintigraphy and the detection of wedge-shaped opacity, consolidation, dilatation in the main pulmonary artery, ground glass attenuation, pleural effusion, and atelectasis in thorax CT.

Study Limitations

In our study, Perfusion-only Modified PIOPED II criteria, which were evaluated using PA chest radiography along with lung perfusion scintigraphy, were used. However, not using lung ventilation scintigraphy is a limitation of our study. In addition, our relatively low number of patients is another limitation.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

This study was approved by the Ethics Committee of Tokat Gaziosmanpasa University Medical Faculty Clinical Researches (Date: 2023-04-10, No: 83116987-246)

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Conflict of Interest
The authors declare that there is no conflict of interest.

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